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TITLE: APPARATUS FOR INCREASING INDUCTION AIR FLOW RATE TO A TURBOCHARGER

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APPARATUS FOR INCREASING INDUCTION AIR FLOW RATE TO A TURBOCHARGER

FIELD OF THE INVENTION

[0001] The present invention relates generally to air induction systems. More particularly, the invention relates to a compact air induction system for increasing induction air flow rate to a turbocharger.

BACKGROUND OF THE INVENTION

[0002] An internal combustion engine typically includes an air induction system with which air is introduced into an intake manifold assembly. In contrast, the air induction system of a turbocharged engine delivers induction air to the impeller of the turbocharger compressor instead of directly to the intake manifold assembly of the engine.

[0003] Prior turbocharged induction systems exhibit problems related to the loss of air induction system pressure head. Common attempts to minimize air induction system head loss include the use of short-length air induction systems, large diameter ducting, or ducting with as few directional changes as possible. However, these solutions are not always possible due to the placement of the engine relative to the surrounding vehicle packaging. Additionally, within the design of the system, certain geometry can be used to minimize flow losses, including diffusers and expansion chambers, at a location where flow must pass through a bend or a bell-mouth transition located within the clean air duct upstream of the inlet to the turbocharger.

[0004] A diffuser can be utilized to increase the static pressure of fluid passing through the system. Typical conical diffusers provide for a gradual conical expansion of the area encompassed by a system, the rate of area expansion being determined by what is known in the art as the "cone angle."

[0005] Additionally, an expansion chamber or plenum may also be utilized to achieve similar results, under certain conditions. The plenum may encompass an expansion or area increase intended to reduce velocity in order to recover the pressure head of the flow. As air or fluid flow enters the plenum, a reduction in flow velocity occurs. The velocity reduction results in the kinetic energy of the fluid being converted to a static pressure rise due to the conservation of linear momentum and the conservation of angular momentum when swirl is present. Due to the static pressure rise, expansion chambers must be carefully designed to avoid increasing overall head loss.

[0006] Furthermore, a bell-mouth transition at the inlet of the turbocharger can be utilized to reduce the amount of head loss and restriction generated as the induction air enters the inlet of the turbocharger.

[0007] Although the use of a single approach, such as either a diffuser, an expansion chamber, or a bell-mouth transition, to reduce static pressure losses is well-known, these three features have not been combined in the prior art to obtain the lowest possible turbocharger entrance losses. Moreover, the prior art air induction systems do not utilize a plenum, diffuser, or other means for restoring static pressure head within the area directly in front of the inlet of the turbocharger. Additionally, packaging and manufacturing constraints have often led to design inefficiencies. Prior to

the invention, the air induction system would have had to include a plurality of dimensional bends or elbows within the clean air duct to satisfy packaging and design constraints. However, such bends or elbows create a high restriction yielding lower than desired pressure conditions at the inlet of the turbocharger compressor. Furthermore, the prior art air induction systems did not utilize the limited space available after the engine and underhood compartment had already been designed to enhance the flow of induction air.

BRIEF SUMMARY OF THE INVENTION

[0008] The present invention alleviates one or more of the shortcomings described above by providing a method and system that enable enhanced air flow to the air intake of an internal combustion engine having a turbocharger. The present invention allows for the reduction of system head loss by minimizing overall restriction within the air induction system.

[0009] In one aspect of the present invention, an air induction system includes a clean air duct directing airflow to the inlet of a turbocharger. The clean air duct includes a plenum or expansion volume for reducing flow velocity and minimizing restriction. The plenum is located within the area directly in front of the turbocharger inlet. The clean air duct may further include a diffuser upstream of the plenum, as well as a bell-mouth transition positioned between the plenum and the inlet to the turbocharger. The diffuser and bell-mouth transition are also configured to reduce overall system restriction and head loss.

[0010] In another aspect of the present invention, an air induction system includes a clean air duct directing airflow to the inlet of a turbocharger that includes a means for reducing the velocity of the air flow within an area directly in front of the inlet to the turbocharger.

[0011] Advantages of the present invention will become more apparent to those skilled in the art from the following description of the preferred embodiments of the invention which have been shown and described by way of illustration. As will be realized, the invention is capable of other and different embodiments, and its details are capable of modification in various respects. Accordingly, the drawings and description are to be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF SEVERAL VIEWS OF THE DRAWINGS

[0012] FIG. 1 is a perspective view of one embodiment of the apparatus of the present invention;

[0013] FIG. 2 is an enlarged perspective view of the apparatus;

[0014] FIG. 3 is an alternate perspective view;

[0015] FIG. 4 is a cross-sectional view of the velocity profile through the plenum of one embodiment of the present invention;

[0016] FIG. 5 is an interior view of one embodiment of the apparatus of the present invention;

[0017] FIG. 6 is an interior view from a different perspective of one embodiment; and

[0018] FIG. 7 is a cross-sectional interior view.

DETAILED DESCRIPTION OF THE INVENTION

[0019] In accordance with the present invention, a method and system are provided that enable enhanced air flow to the air intake of an internal combustion engine having a turbocharger. In the air induction system provided, various components are integrated into a clean air duct in such a manner as to minimize system head loss.

[0020] FIGS. 1 and 2 illustrate perspective views of one embodiment of the air induction system in accordance with the present invention. As shown in FIG. 1, the air induction system 100 for use in an internal combustion engine having a turbocharger includes a clean air duct 102. The clean air duct 102 is operable to deliver induction air flow to the turbocharger inlet 110 from an air filter or cleaner (located within a filter housing 101), which in turn draws air from an air intake (typically located within the engine bay of the motor vehicle (not shown)). The clean air duct 102 illustrated integrates a diffuser 104, a plenum 106, a bell-mouth transition 108, and the turbocharger inlet 110 and enhances the flow of induction air at the turbocharger inlet 110. In the preferred embodiment, the clean air duct 102 upstream of the diffuser 104 is configured to have a clean air tube 103 with an inner diameter of 70 mm, although other sized diameters could be used.

[0021] FIG. 2 is an enlarged view of the diffuser 104, the plenum 106, the bell-mouth transition 108, and the turbocharger inlet 110. The plenum 106 is provided within the clean air duct 102 in an area directly in front of the turbocharger inlet 110 and replaces one or more bends or elbows within the clean air duct 102 that would otherwise be present. Such bends or elbows

almost always create a high restriction flow path, which reduces the flow rate of induction air. The juxtaposition illustrated in FIG. 1 among the diffuser 104, the plenum 106, and the accompanying clean air duct 102 effectuates a 180 degree change in the direction of the flow of induction air within the clean air duct 102 with a minimum of system head loss.

[0022] FIG. 2 further illustrates that the plenum 106 is located within the clean air duct 102 downstream of the diffuser 104. Specifically, the plenum 106 is in direct communication with the diffuser 104. Additionally, the diffuser 104 connects to the plenum 106 along the majority of the length of the cylindrical wall 112 of the plenum 106. As illustrated in FIG. 1, the juxtaposition of the outlet of the diffuser 104 with the plenum 106 results in a 90 degree change in the direction of the flow of induction air within the clean air duct 102.

[0023] Additionally, the plenum 106 is located within the clean air duct 102 upstream of the bell-mouth transition 108 and the turbocharger inlet 110. As shown in FIG. 3, the bell-mouth transition 108 is configured to reduce the cross-sectional area encompassed by the plenum 106. The bell-mouth transition 108 includes a transition tube 122 having a transition tube inlet 120 and a transition tube outlet 124.

[0024] As illustrated in FIG. 2, the turbocharger inlet 110 is configured to be circular in shape. Accordingly, the bell-mouth transition tube outlet 124 is also configured to be circular in shape, as shown in FIG. 3. Additionally, the radius of the circular interior surface of the bell-mouth transition tube 122 may range from approximately 3 to approximately 30% of the effective

diameter of the turbocharger inlet 110. However, optimal results occur when the radius is approximately 20% of the effective diameter of the turbocharger inlet 110. In a preferred embodiment the diameter of the bell-mouth transition tube 122 is 53.0 mm.

[0025] As illustrated in FIG. 4, the overall operation of the plenum 106 is described as follows. The plenum 106 provides a cross-sectional area increase within the clean air duct 102 which reduces overall restriction by not forcing the flow of induction air through a particular path (as shown in FIG. 4). The induction air flow enters the plenum 106 directly from a diffuser outlet 126. The plenum 106 is configured to increase the cross-sectional area encompassed by the clean air duct 102. This increase in the cross-sectional area encompassed by the clean air duct 102 results, in part, from the outward expansion of the inner surface of the plenum 106 between the diffuser outlet 126 and the plenum inlet 116, as shown in FIG. 4. FIG. 2 illustrates an exterior view of the outward expansion of the plenum 106 at the plenum inlet 116. The gradual increase in the area encompassed by the clean air duct 102 produces a reduction in the induction air flow velocity within the expansion volume, or plenum 106. In a preferred embodiment, the cross-sectional area of the clean air duct 102 increases from 4729.48 mm^2 at the diffuser outlet 126 to a maximum of approximately 7482 mm^2 at the center of the plenum 106. Moreover, in the preferred embodiment, the maximum horizontal cross-sectional area of the plenum 106, which is the cross-sectional plane that is perpendicular to the axis of symmetry of the diffuser outlet 126, is the

horizontal plane of FIG. 3 that would be located at the vertical center or mid-point of the plenum 106.

[0026] The reduction in velocity within the plenum 106 is especially important as restriction and head loss are proportional to velocity squared, as evidenced by the well known Darcy-Weisbach equation. In particular, the plenum 106 illustrated in FIG. 2 is configured to encompass a volume such that the reduction of the induction air flow velocity within the plenum 106 results in optimal engine performance. For the plenum 106 illustrated, optimal results are achieved when the velocity of the induction air flow within the plenum 106 is reduced to less than 75 m/s, as shown in FIG. 4. However, depending upon engine application, other embodiments may vary the volume of the plenum 106 to achieve maximum engine output performance.

[0027] The interior of the plenum 106 is configured to be cylindrical or tubular in shape, as illustrated in FIG. 5 by the inner circular surface 130 of the plenum 106. FIG. 5 further illustrates that the radius of the interior of the plenum 106 is constant such that the longitudinal cross-sectional area, which is perpendicular to the axis of symmetry of the plenum 106, encompassed by the expansion volume or plenum 106 is uniform lengthwise. In a preferred embodiment, the inner radius of the plenum 106 is 43.5 mm.

[0028] The longitudinal cross-sectional area encompassed by the plenum 106 is terminated axially on the side of the plenum 106 that is opposite the bell-mouth transition inlet 118 by a plenum wall 114, as illustrated in FIG. 2. In a preferred embodiment, the interior distance from the plenum wall 114 to the bell-mouth transition inlet 118 is 86.0 mm.

[0029] As shown in FIG. 5, the plenum inlet 128 provides for an outward expansion of the plenum 106 which culminates with the plenum wall 114. The interior surface of the plenum inlet 128 connects the plenum wall 114 with the inner circular surface 130 of the plenum 106 via a convex or outward curving surface. Additionally, this convex interior surface of the plenum inlet 128 is smooth.

[0030] The plenum wall 114 is perpendicular to the axis of symmetry of the plenum 106 and forms a barrier to and contributes to the redirection of the flow of induction air within the plenum 106, as illustrated in FIG. 4. The interior of the plenum wall 114 is a smooth, flat surface 132, which minimizes system head loss generated along the surface of the plenum wall 114. The inner circular surface 130 of the plenum 106 is smooth, as well, which further minimizes system head loss generated along the inner circular surface 130 of the plenum 106.

[0031] The induction air flow exits the plenum 106 by passing through the bell-mouth transition inlet 118 and into the bell-mouth transition tube 122. As illustrated in FIG. 4, the induction air flow velocity increases as it passes through the bell-mouth transition inlet 118 and into the bell-mouth transition tube 122. From the inner circular surface 130, the bell-mouth transition tube inlet 118 exhibits a smooth, concave, or inward bending, interior surface. In a preferred embodiment, the smooth, concave interior surface of the bell-mouth transition inlet 118 is circular in cross section and has a 10.6 mm bell-mouth radius.

[0032] The increase in induction air flow velocity within the bell-mouth transition tube 122 results from the decrease in the cross-sectional area encompassed by the clean air duct 102. As shown in FIG. 5, the reduction in the cross-sectional area encompassed by the clean air duct 102 is created by the juxtaposition of the plenum 106, the bell-mouth transition inlet 118, and the bell-mouth transition tube 122. In a preferred embodiment, the bell-mouth transition tube 122 has a cylindrical interior with a constant inner radius of 26.5 mm, such that the longitudinal cross-sectional area of the bell-mouth transition tube 122 is constant.

[0033] FIG. 2 further illustrates that the plenum 106 discharges the air flow through the bell-mouth transition 108 located upstream of the turbocharger inlet 110. As illustrated in FIG. 3, the bell-mouth transition tube 122 is a round, circular transition piece that is utilized to connect the plenum 106, via the bell-mouth transition 108, with the turbocharger inlet 110. In a preferred embodiment, the cross-sectional area encompassed by the bell-mouth transition tube 122 is constant as the induction air flows from the bell-mouth transition tube inlet 120 to the bell-mouth transition outlet 124. In a preferred embodiment, the combined length of the bell-mouth transition inlet 118 and the bell-mouth transition tube 122 is 33.5 mm.

[0034] FIG. 5 shows one perspective of the smooth inner surface of the bell-mouth transition tube 122. FIG. 6 provides an alternate perspective of the interior surface of the bell-mouth transition tube 122. The interior surface of the bell-mouth transition tube 122 illustrated is configured to have a smooth, circular inner surface to enhance the flow of air at the turbocharger inlet 110.

The circular shape and smooth inner surface of the bell-mouth transition tube 122 is particularly important to minimizing system restriction and head loss that would otherwise be generated as induction air flows through the bell-mouth transition tube 122.

[0035] FIG. 3 further illustrates that the plenum 106 receives air flow downstream of a diffuser 104. The diffuser 104 illustrated is in communication with the plenum 106. Additionally, the diffuser 104 is configured to be curved along its entire length. In a preferred embodiment, the diffuser 104 has an inner diameter of 70 mm at its entrance. Also in a preferred embodiment, the diffuser outlet 126 has approximately a 77.6 mm inner diameter.

[0036] FIG. 5 illustrates that the diffuser 104 is an annular diffuser 134 that radially diverts the flow of induction air and facilitates the replacement of one or more bends or elbows within the clean air duct 102 that would otherwise be present. In a preferred embodiment, the diffuser 104 has a centerline length of 118 mm. The annular diffuser 134 illustrated is configured to possess a smooth inner surface 136. The conical shape and smooth inner surface 136 of the annular diffuser 134 further diminish head loss. Additionally, as illustrated in FIG. 1, the curvature of the diffuser 104 effectuates a 90 degree change in the direction of the flow of induction air within the clean air duct 102.

[0037] FIG. 6 illustrates an alternative perspective of the interior surfaces of the diffuser 104, plenum chamber 106, bell-mouth transition inlet 118, and bell-mouth transition tube 122. The smooth interior surface of each

of the diffuser 104, plenum 106, bell-mouth transition inlet 118, and bell-mouth transition tube 122 contributes to the reduction in overall system head loss.

[0038] Preferably, the interior of the diffuser 104 is configured to be conical in shape. As illustrated in FIG. 7, the cross-sectional area encompassed by the inner conically shaped wall 138, 140 of the diffuser 104 increases longitudinally at a rate established by the cone angle. The increase in the cross-sectional area encompassed by the inner conically shaped wall 138, 140 of the diffuser 104 reduces the velocity of induction air flow and restores static pressure head. The cone angle of the diffuser 104 is variable, preferably between approximately 4 to approximately 16 degrees. However, for the diffuser 104 illustrated, optimal results occur when the cone angle is approximately 12 degrees. Additionally, the interior surface 142 of the diffuser 104 is configured to be smooth, which further minimizes head loss.

[0039] Additionally, FIG. 7 provides a view of the cross-section of the plenum 106, bell-mouth transition inlet 118, and bell-mouth transition tube 122. The cross-section of the plenum 106 is circular or tubular in shape, with a constant inner diameter, which is further illustrated in FIG. 5 by the inner circular surface 130 of the plenum 106.

[0040] FIG. 7 also illustrates that the interior of the bell-mouth transition inlet 118 effectuates a reduction in the longitudinal cross-sectional area encompassed by the clean air duct 102, as the induction air flows from the plenum 106 and enters the bell-mouth transition tube 122. In a preferred embodiment, the longitudinal cross-sectional area encompassed is reduced from 5941.7 mm^2, the longitudinal cross-sectional area of the plenum 106, to

2205.1 mm², the longitudinal cross-sectional area of the bell-mouth transition tube 122.

[0041] The air induction system 100 described herein is effective to reduce the overall restriction and head loss within the system 100. The invention includes a novel placement of a means for reducing the air flow velocity within the air induction system that offers advantages over the prior art. The invention further includes a novel juxtaposition of a diffuser, a plenum, and a bell-mouth transition within an air induction system. By reducing the overall system restriction and head loss, the physical conditions of the air upstream of the entrance to the turbocharger are improved, which prevents engine performance from significantly deteriorating.

[0042] While the preferred embodiments of the invention have been described, it should be understood that the invention is not so limited and modifications may be made without departing from the invention. Additionally, while the embodiments here within are discussed for application with a turbocharged air induction system, they may also be adapted for other systems. For example, the embodiments may be adapted for a naturally aspirated engine air induction system by interchanging the naturally aspirated throttle body with the turbocharger. Therefore, the scope of the invention is defined by the appended claims, and all devices that come within the meaning of the claims, either literally or by equivalence, are intended to be embraced therein.